Photorealistic XR Part I

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CONTENTS

Part I

Background

- Digital Media Ecosystem (Movie, Game, VR)
- Photorealistic Rendering and Composition
- Human Visual System
- Photorealistic Mixed Reality
- High-fidelity XR Telepresence and Collaboration





Wellywood

- NZ is famous for its nature and stunning CG-like scenery, made famous by "The Lord of the Rings".
- NZ landscapes appear in many films and commercials.
- Wellington has a strong and thriving film industry, with famous directors such as Peter Jackson and James Cameron living nearby.
- Wellington is home to Oscar winning visual effects companies Weta Workshop and Weta Digital.





Milford Sounds, South Island

Matamata, North Island





Wellywood VFX Powerhouse (Highest Grossing Films)

• Five among top ten highest grossing films have been post processed in Wellington.



Rank ≑	Peak 🗢	Title 🔶	Worldwide gross ◆	Year 🗢	Reference(s)
1	1	Avengers: Endgame †	\$2,796,274,401	2019	[# 1][# 2]
2	1	Avatar	\$2,789,679,794	2009	[# 3][# 4]
3	1	Titanic	\$2,187,463,944	1997	[# 5][# 6]
4	3	Star Wars: The Force Awakens	\$2,068,223,624	2015	[# 7][# 8]
5	4	Avengers: Infinity War	\$2,048,359,754	2018	[# 9][# 10]
6	3	Jurassic World	\$1,671,713,208	2015	[# 11][# 12]
7	7	The Lion King †	\$1,602,286,738	2019	[# 13][# 2]
8	3	The Avengers	\$1,518,812,988	2012	[# 14][# 15]
9	4	Furious 7	\$1,516,045,911	2015	[# 16][# 17]
10	5	Avengers: Age of Ultron	\$1,405,403,694	2015	[# 18][# 17]

Wikipedia, September 2019





Computer Graphics at Victoria University of Wellington



Victoria University has one of the largest Computer Graphics academic group in Oceania (seven faculty members in Engineering, more members in the related areas across Media Design and Films)

CMIC Computationa Media Innovation Centre



CMIC – Centre of Computational Media Innovation







CMIC – Centre of Computational Media Innovation







CMIC Office and Members

- CMIC office has brand new research facilities located in centre of Wellington city.
- Immersive Visualisation Lab and Capturing and Modeling Lab.
- Currently 25 members and rapidly growing.
- Led by Taehyun Rhee (director) and Ken Anjyo (co-director)
- 9 Academic/Research staff
- 5 Professional staff (programmers, designers)
- 7-10 Students (PhD, Master)







Link Academic Research to Industry







Digital Media (Movie and Game) Ecosystem







User Experience







Virtual Reality (VR) Ecosystem (before 2015)



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Virtual Reality (VR) Ecosystem (after 2015)





Telepresence, Interaction

Immersion, Experience



(\$108M, 2014 → \$13B 2019, USD)





Virtual Reality (VR) Ecosystem (Issue)





Telepresence, Interaction

Immersion, Experience



(\$108M, 2014 → \$13B 2019, USD)





Problem: Current VR with 360 Video Presence without interaction



360 videos shown in VR display can provide a wide field of regards. This provides a sense of telepresence at the captured location <u>but has no</u> <u>interaction</u> except head rotations



Our MR 360 Solution: MR with 360 Video + Interactions Presence with interaction



CMIC and DreamFlux team developed a novel solution for automatic lighting, cinematic blending of 3D digital objects into 360 films in real-time. The result provides users the <u>illusion of playing with</u> <u>objects in high telepresence</u>.

made with



Scientific and Technical Challenge



- High performance computation: million times speed up
- Automatic pipeline: intelligent algorithms

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• Easy communication: convenient interfaces for end users



Realistic Lighting, Rendering, and Composition (off-line)







Technical Challenges

• Realistic Rendering (path tracing)

- Real-world lighting
 - Image based lighting (IBL)
- Illumination Composition
 - Manual work \rightarrow Differential Rendering [Debevec98]





Reconstruct Path Tracing [TVCG 2017]

Input 20% pixels



Our Recovery





CNN and Matrix Completion [TVCG 2017]







Comparison [TVCG 2017]







Image Based Lighting (IBL)







Sky Browser [PG 2014]

- Developed in collaboration with Weta Digital
- In use at VFX pipeline: film credit for "The Hobbit: The Battle of the Five Armies"









Latent and Illumination Space [PG2019, PG2020]







Challenges for Interactive Mixed Reality

- Performance
 - Real-time solutions for GI, IBL, differential rendering
 - High frame rate (> 90FPS, stereoscopic) for modern HMDs
- Viability
 - No pre-computation (Spherical Harmonics) to adapt live video stream
 - Adapt conventional LDR (8 bits) 360 video for IBL needs HDR (24 ~ 32 bits)
- Visual quality
 - Seamless blending between virtual and real objects for high presence





Human Visual System

• The ultimate receiver of the image is the "human eye"







Human Visual System

- Metric in realistic blending of AR/MR: "seamlessness", "presence"
 - The impression that the synthetic object belongs and blended in the real-world scene
 - The presence of synthetic object in the real-world scene







Perceptually based rendering [PG14]



- 160x80 is not perceptually noticeable for all scenes
- ~99% saving over the typical VFX studio setup





Perceptual Study of Dynamic Range



HDR LM 5024 x 2512

HDR LM 320 x 160 (99% reduction) Tone mapped LDR LM 320 x 160 (99% reduction + LDR)





360° panoramic videos







MR360 [IEEE TVCG, IEEE VR 2017]







IBL: Diffuse Reflection

- Material and Light are reciprocal in illumination [Ramamoorthi and Hanrahan 02]
- Low Resolution was enough for HVS









IBL : Glossy Specular Reflection







Real-time IBL

- Roughness
 - 0.0 to 1.0 (+0.25)

- Different materials
 - 500 FPS (1280 x 720)

- Different lights
 - LDR (1920x960 ~ 2048x1024)







Image Based Lighting









Image Based Shadowing (IBS)







Image Based Shadowing (IBS) – Light Detection

- Detect dominant light patches using thresholding of luminance
 - Box blur before thresholding to reduce noisy patch
 - Breadth-first search for connectivity of the patch





IBS Examples









Differential Rendering



(a) Background 360 video



(c) Objects + LS + Background



(e) Difference (c) x (d) - (b)



(b) Local Scene (LS) w/o Object



(d) Object Matte



(f) Final Composition: objects + (e) + background













MR360-Underwater: Immersive Underwater MR Toolkit [ISMAR 19]







MR360-Underwater: Four additional underwater effects (caustics)

Without Caustics

With Caustics







MR360-Underwater: Four additional underwater effects (God-rays)

Without Virtual God-rays

With Virtual God-rays







MR360-Underwater: Four additional underwater effects (Fog)

Without Fog

With Fog







MR360-Underwater: Four additional underwater effects (Particulates)

Without Particulates

With Particulates







Evaluation

Ambient Lighting

MR360

MR360-Underwater







User Study (visual quality and presence)









Virtual Tour in Mixed Reality

Departure

Com

TO of Sin and F Singa Sund 1-5p

#Sing





Virtual Tour in Mixed Reality

Departu

Com

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GENERATIONS SIGGRAPH2018







Augmented Virtual Teleportation (AVT) [TVCG, IEEEVR 2020]





XR Remote Collaboration

Teleportation from A to B







Local Space B





Teleportation from A to B







Local Space B





Collaborate with People at B (Collaboration Site)

Traveller



Local Space A



Local Space B Collaboration Site





Remote Workspace Collaboration





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GTON

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Being there

Feel there

Suller.









Customer Success Team







Video Conference



May Kishon

Amon Nir



Rotem Yifat









Telecollaboration in VR



Local Space A

Local Space B





Telecollaboration in AR



Holoportation by Microsoft



Limited Telepresence



Holoportation by Microsoft



Local Space B





AVT for Remote Workspace Collaboration [IEEE VR, TVCG 2020]







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AVT Remote Collaboration = Live (VR + AR + MR)





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System Overview

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Part II

- Background
- Image Based Lighting, Illumination,
- Machine Learning for XR
- And more







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Pacific Graphics 2020

Pacific Graphics is set to arrive in Wellington, New Zealand (Aotearoa) for the first time ever in the Southern Hemisphere.

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